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Original Research

Development of various reaction abilities and their relationships with favorite play activities in preschool children

Running head: Reaction time in preschool children

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ABSTRACT

This study examines the development of various reaction movements in preschool children, and the relationship between reaction times and favorite play activities. The subjects were 167 healthy preschool children aged 4 to 6 (96 boys and 71 girls). This study focused on the reaction times of the upper limbs (Reaction-1: release, 2: press) and the whole body (Reaction-3: forward jump). The activities frequently played in preschools are largely divided into dynamic plays (tag, soccer, gymnastics set, dodge ball, and jump rope) and static plays (drawing, playing house, reading, playing with sand, and building blocks). The subjects chose three cards picturing their favorite plays, out of ten cards depicting ten different activities. All ICCs of measured reaction times were high (0.73-0.79). In addition, each reaction time shortened with age. Reaction-1 showed a significant and low correlation with Reaction-3 (r =0.37). The effect size (ES) of the whole body reaction time was the largest. Whole body reaction movement, which is largely affected by the exercise output function, develops remarkably in childhood. Children who liked "tag" were faster in all reaction times. The children who chose "soccer" were faster in Reactions-2 and 3. In contrast, children who liked "playing house" tended to have slower reaction times. Dynamic activities, such as tag and soccer, promote development of reaction speed and agility in movements involving the whole body. Preschool teachers and physical educators should re-examine the effect of tag and use it periodically as one of the exercise programs to avoid unexpected falls and injuries in everyday life.

KEY WORDS: reaction time, fall, dynamic activity, agility

INTRODUCTION

In Japan today, accidents and injuries related to children's falls are increasing, while their physical fitness and motor abilities are declining. There are many children who suffer head injuries due to underdeveloped reaction of the upper limbs when slipping, tripping or falling, particularly in preschools (24). Similar accidents and injuries in children are also increasing every year in Germany (8). These injuries require not only high financial burden for the treatment (19); they also may adversely affect the children's attitude toward physical activity in the future (18).

Whereas the above accidents and injuries occur frequently, changing lifestyles, marked decreases in outside play, the spread of video games, etc., are also considered to be contributing factors. Influenced by this trend, it may be assumed that the ability to move a body quickly and adequately is not developed sufficiently in young children. Although each preschool tries to prevent injuries caused by falling, teachers may not be able to offer enough exercise programs to encourage their students' physical development.

When encountering dangerous and unexpected physical obstacles the ability to react quickly is important for evading falls and injury. This quickness can be measured by reaction time, which is defined as the time between the onset of stimulus and the beginning of an overt response (7). The reaction time is a variable reflecting a central nerve function and a peripheral function related to appearance of a certain movement, as used in many studies (23, 25). Originally, the reaction time was mainly measured with just a small muscle, such as the hand and fingers (2, 14). However, evaluating reaction time with respect to a small muscle is insufficient when considering the performance of a particular complex movement. Many have recognized that it is also necessary to measure the reaction time of the whole body (1, 4, 5).

Reaction movements in modern-day children have been little studied, despite the fact that a delay in reaction time relates to risk of serious injury. Preschool children rarely take reaction time tests since they often do not understand the task, and the development of reaction movements with age and their relationships with favorite play activities have not been well examined.

Although the development of the nervous system during childhood is remarkable, the ability to move quickly after a stimulus is thought to be affected greatly by learning experience (21). Matsuura et al. (20) reported that preschool children who prefer playing tag performed better than other children in fundamental motor skills (running, jumping, and throwing). In addition, a whole body reaction movement such as jumping forward is very complex, and its development may be strongly affected by the experience of dynamic play that uses the whole body. Hence, the following hypothesis was set in this study: The development of reaction movements in preschool children differs by the kind of movement or the body parts involved, and the reaction times of children who like dynamic play are faster.

It will be necessary to examine the development of each reaction movement and the effect of play thereon in order to offer useful exercise programs in preschool. This study aimed to examine the development of reaction movement in the upper limbs and the whole body in preschool children, and the relationship between the above stated reaction time and their favorite plays.

METHODS

Approach to the problem

Reaction time may differ according to reaction movement patterns. Even in the reaction movement of the upper limbs, there are two types. One is the movement of pushing a button in response to stimulation; another is the movement of releasing a hand from a switch, as in an immediate pull-away reaction when accidentally touching something very hot. It may be regarded that the former is a voluntary movement and the latter is the inherent reflex movement that is similar to a flexion reflex. These reaction movements depend mainly on small muscle activity, and are largely affected by information processing functions. On the other hand, reaction movements of the whole body are largely affected by the exercise output function.

Recently, there have been many children who have suffered head injuries due to underdeveloped reaction of the upper limbs or the whole body when slipping, tripping or falling (8, 24). Hence, this study first examined the development of the reaction time of each different movement stated above. Each reaction time is thought to be affected strongly by experience with dynamic play, which uses the whole body, among everyday activities. After classifying the preferred plays as either dynamic or static, relationships between plays and the movement reaction time were examined. Furthermore, the differences between each reaction time by the number of dynamic play choices were examined.

Subjects

The subjects were 167 healthy preschool children aged 4 to 6 (96 boys and 71 girls). Table 1 shows their physical characteristics. The data were similar to the mean values of findings that were performed nationwide on infants by Ministry of Health, Labour and Welfare, and the physical characteristics of subjects were almost the same as that of general infants. Informed consent was obtained from all parents and preschool teachers after a full explanation of the experimental project and its procedures. Oral explanation was given to the subjects on the measurement day. All subjects consented to the experimental measurement. This study was approved by the Human Rights Committee of Kanazawa University.

+++ < Table 1 > near here +++

Reaction time experiment

1) Reaction time of release movement (Reaction-1)

Subjects sat on a chair facing a luminescent device. Reaction time was measured by an original measuring device (Takei Scientific Instruments Co., Ltd., Niigata City, Japan). Measurement began with confirming the light stimulation that a tester sends randomly, to quickly releasing both hands (fingers) from the switch (Fig.1). When measuring reaction time, it is very important that the timing of the stimulus is not predicted by the subject. It was reported that average simple reaction time is about 190 msec in vision stimulus appearance equipment (3). Therefore, when a recording was 150 or less msec in this study, measurement was carried out again.

2) Reaction time of press movement (Reaction-2)

Subjects sat on a chair facing a luminescent device and put both hands on the table. Reaction time measurement ran from confirming the light stimulation that a tester sends randomly, to pressing the forward switch quickly. In consideration of the influence of handedness, both of the above tests were performed by both hands, and the better value was selected (Fig.2). The movement of pressing is more optional than Reaction-1.

3) Whole body reaction time (Reaction-3)

Subjects stood on the start mat with both bare feet together. Reaction time measurement ran from confirming the light stimulation that a tester sends randomly, to when subjects jumped to the forward mat (Fig.3).

When measuring the whole body reaction of young men, an upward jump has generally been used. However, since preschool children are inexperienced in the upward jump, the forward jump with a clear arrival target was adopted. In addition, the same tester measured all reaction times.

The test was performed three times after a few practices, and the mean value of the trials was adopted. Because test time was limited, children took appropriate supplementation and enough hydration before and after the test. The measurement was carried out in the morning (from 10:00 to 11:30).

+++ *< Figure 1-3 > near here* +++

Selection of children's favorite play activities

The play activities frequently experienced in preschools are largely divided into dynamic plays and static plays. The subjects chose three cards picturing their favorite plays, from ten cards depicting ten different activities. The five dynamic plays the subjects chose from were tag, soccer, children's gymnastic set (circuit), dodge ball, and jump rope. The five static plays the subjects chose from were drawing, playing house, reading a picture book, playing with sand, and building blocks. In order to remove the influence of other friends' replies, the homeroom teacher observing the children always interviewed each child one at a time, and asked the child to select plays.

+++ *< Figure 4> near here* +++

Statistical Analyses

1) The reliability of measurement values exerted by various reaction tests was examined by ICC (Intraclass correlation coefficient). To examine the developmental profile of each reaction time, Two-way ANOVA (analysis of variance; gender and age) was used to reveal the mean differences between gender and ages of each reaction time. The post hoc comparisons were made using Tukey's HSD tests. Effect size (ES) was calculated to examine the size of the mean differences of each reaction time. Additionally,

relationships between each reaction time were examined using partial correlation coefficient in considering age effect.

2) For each play, every reaction time was compared between two groups of who did or did not like the play. At that time, Two-way ANOVA (age and category) was used to reveal the mean differences among ages and categories of each reaction time. The post hoc comparisons were made using Tukey's HSD tests.

3) All subjects were divided into the following four choice groups: Group 1 chose three dynamic plays, Group 2 chose two dynamic plays and one static play, Group 3 chose one dynamic play and two static plays, and Group 4 chose three static plays. ANCOVA (analysis of covariance; age is covariates) was used to reveal the mean differences between these groups for each reaction time.

The criterion level for significance was set at $p \leq 0.05$.

RESULTS

All ICCs of reaction times measured were high (0.73-0.79). The result of two-way ANOVA (gender and age) showed insignificant difference between boys and girls. Hence, the following analysis used pooled data of both sexes.

On the other hand, significant differences were found between ages for each reaction time. Each reaction time shortens with age. Figure 5 shows the changes of each reaction time with age. Reaction time of the release movement (Reaction-1) shortened by about 50msec (ES: 1.37) across two years from age 4 (316.6msec) to age 6 (268.4msec). Likewise, reaction time of the press movement (Reaction-2) shortened by about 110msec (ES: 1.55) across two years (age 4: 598.2msec, age 6: 484.3msec). Finally, whole body reaction time (Reaction-3) shortened by about 200msec (ES: 1.96) across two years (age 4: 975.0 msec, age 6: 777.6msec).

+++ < *Figure 5*> *near here* +++

All reaction times showed significant and low to moderate partial correlations with reaction tests (Reactions-1 and 2: r=0.44, Reactions-1 and 3: 0.37, Reactions-2 and 3: 0.66). Figure 6 shows the frequency distribution (ratio) of the plays that children selected. In boys, "soccer (49%) ", which is a dynamic play, was the most frequently selected, followed by "tag (42%)", and "circuit (38%)". "Playing house (70%) ", which is a static play, was the most frequently selected in girls, followed by "playing with sand (41%)", and "jump rope (37%)".

+++ < *Figure 6* > *near here* +++

Table 2 shows the results of two-way ANOVA that examined the mean differences among ages and categories for each reaction time. Children who liked "tag" were faster in all reaction times. The children who liked "soccer" were faster in Reactions-2 and 3. In contrast, children who liked "playing house" tended to be slower in all reaction time to the others.

+++ < *Table2* > *near here* +++

Figures 7-9 show the results of ANCOVA that examined the mean differences among each group, divided by the selected number of dynamic plays, for each reaction time. In every reaction time, significant differences were found between groups. Group 1, who chose three dynamic plays, was faster than the others when performing Reactions-2 and 3. On the whole, children who chose many dynamic plays were faster than the others.

+++ < *Figure 7-9* > *near here* +++

DISCUSSION

The reaction time in preschool children has not been well measured until now, because preschoolers usually have difficulty understanding the test methods for reaction time.

However, in this study using preschool children aged 4 to 6 as subjects, ICCs of all tests were over 0.7. Hence, it is thought that they can indeed comprehend the task, and the measurement is reliable. In fact, in our previous study (22), we confirmed that the approximately 40% of preschool children have already experienced playing a video game. In modern-day Japan, there are many children playing video games, therefore children's interest in reaction time tests that include a game element may be high.

Insignificant gender differences were found in each reaction time test. Furui et al. (13) reported that gender differences in reaction times appear from about 8 years old, and develops predominantly in boys. It was also concluded that this difference depends on gender dimorphism in peripheral exercise function (myofunction), but not in the central exercise function. Since there are insignificant gender differences in muscle function during childhood, this could also explain why gender differences in reaction time may not be found. On the other hand, significant age differences were found in all reaction times. The ability to exert muscle strength explosively depends largely on the function of the corticospinal tract. Hence, the conduction velocity of the central nervous system in the corticospinal tract is inferred to be shortened with age.

The binding of cortical motor neurons, the growth and myelination of corticospinal axons, the excitatory maturation of cortical or spinal levels, etc., may all be affected (9, 11). Furthermore, Fietzek et al. (11) reported that among various movements, those producing velocity simply have earlier maturational timing, and more complicated movements have later maturational timing. Significant differences were confirmed in age-related changes between Reaction-1 and Reaction-2 in this study, even in the same reaction time on upper limbs. The present results may support their report.

Since the effect size (ES) of Reaction-3 was the largest, whole body reaction time may develop remarkably in childhood. In this study, three kinds of reaction time

(Reaction-1, Reaction-2 and Reaction-3) were examined. Reaction movements may be more voluntary and complex from Reaction-1 to Reaction-2, with Reaction-3 being the most so. As age increases, time required for the output shortens from Reaction-1 to Reaction-3; a marked developmental change may have affected the exercise output function more than the information processing function. Therefore, the experience of exercise plays that use the whole body may greatly affect whole body reaction time. In addition, Reaction-1 showed significant low correlations with Reaction-3 (r =0.37). Although both tests evaluate agility, their relationship is low and it was guessed that each test has evaluated different abilities reflecting the exercise output function and the information processing function.

Fujiwara et al. (12) measured the reaction time in elderly people performing upper, forward and backward jumps after a light stimulus. They reported that the forward jump was the longest, followed by the backward jump, with the upward jump the shortest. Because the forward jump requires a remarkable shift in center of gravity toward the jump direction before the kick, it may have a particularly longer movement time. It is assumed that everyday exercise experience largely affects the quick forward jump in response to stimuli.

In addition, reaction time is strongly influenced by differences in posture just before the exercise (16). Particularly, a position change of the limbs and trunk just before movement is strongly related to reaction time (26). In short, if a preparation necessary for exercise performance is simplified by a change of limb position, the reaction time shortens (17). During the Reaction-3 test in this study, start posture was not specifically explained to the subjects. However, individual differences were found in standing position, such as standing posture or bent forward-leaning posture, when waiting for a signal (luminous stimulus). Exercise experiences such as tag, foot race, dodge ball, etc. may have greatly affected these postures. In the analysis of the relationships between each reaction time and the plays, it was suggested that there is significant positive effect from playing tag and soccer. It is inferred that dynamic plays increase the reaction speed and agility of whole body movement.

Kagaya et al. (15) examined the exercise intensity of tag in children and reported that tag is an effective exercise in improving endurance. However, the effect of tag in improving children's ability to quickly move has not been well examined. In this study, it was suggested that the effect of tag on reaction time is high. Recently, it was reported that whole body motions requiring quick movement such as a quick turn, and thinking strategies such as situational judgment, are effective for promoting development of a cerebral motion control function or an intelligence function (6, 10). From now preschool teachers should introduce these exercises positively into an exercise program.

On the other hand, it was suggested that there is significant negative effect from playing house. Although playing house is an important activity for developing creativity and social skills, children who chose it tended to select other static plays as well. Hence, their reaction time might be even slower. It will be necessary for preschool teachers to offer such children the opportunity to exercise in a positive manner. It is noted that children who chose many dynamic plays were faster in reaction time to the others. This indicates that experiencing different types of exercise is effective for shortening reaction time, even more so than only performing a single dynamic activity. Considering this, experiencing various exercises may contribute more to the effective development of reaction times than a single specific exercise.

PRACTICAL APPLICATIONS

In this study, from examining reaction time results of different movement patterns, it was concluded that remarkable developmental change occurs more in an exercise output function than in an information processing function during early childhood. Dynamic plays such as tag and soccer develop the reaction movement speed and agility of whole body movement. In particular, it was indicated that performing not just a single activity but also many different types of exercise is effective for developing reaction movements. It will be necessary to positively introduce various dynamic plays in childhood to prepare for future sports activities, as well as to avoid unexpected falls and injuries in everyday life. Preschool children, regardless of gender, can enjoy group exercises, such as tag, that include a game element. Preschool teachers and physical educators should re-examine the effect of tag and use it periodically as one of the exercise activities.

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Table1 Physical characteristics

		n	Height (cm)	Weight (kg)
4yrs	Boys	28	104.7±3.8 *	16.5±1.7
	Girls	15	101.8±3.9	15.9±2.0
5yrs	Boys	45	109.4±4.2	18.4±2.6
	Girls	40	107.3±4.5	17.5±2.2
6yrs	Boys	23	113.5±4.0	19.7±2.8
	Girls	16	113.6±3.7	19.8±2.7

*: Mean ± SD

Table 2 Results of two-way ANOVA that examined the mean differences among ages and categories of each reaction time

Measuremnet item	Play	Category	n	4yrs	(n)	5yrs	(n)	6yrs	(n)	Two-way ANOVA		
											F-value	post-hoc
	Tag	select	56	302.8±29.3	(12)	291.0±37.6	(28)	254.1±26.2	(16)	F1	5.58 *	S>N
Upper-limb		non	111	322.7±27.8	(31)	299.2±50.4	(57)	277.7±45.2	(23)	F2	11.78 *	6>5>4
release movement										F3	0.51	
(Reaction-1)	Play house	select	79	322.1±31.3	(20)	306.5±53.8	(40)	275.2±49.0	(19)	F1	4.21 *	**N>S**
		non	88	311.3±27.2	(23)	287.6±37.2	(45)	262.3±30.2	(20)	F2	13.32 *	6>5>4
										F3	0.15	
	Tag	select	56	561.9±71.3	(12)	498.9±75.4	(28)	477.4±73.9	(16)	F1	5.24 *	S>N
Upper-limb		non	111	613.3±77.5	(31)	521.1±61.6	(57)	489.5±62.6	(23)	F2	21.56 *	6, 5>4
press movement										F3	0.76	
(Reaction-2)	Soccer	select	56	583.2±87.7	(14)	482.2±54.8	(27)	458.3±64.5	(15)	F1	9.12 *	S>N
		non	111	606.0±73.8	(29)	526.9±67.5	(58)	501.7±64.1	(24)	F2	29.32 *	6, 5>4
										F3	0.33	
	Play house	select	79	634.8±88.2	(20)	529.1±59.3	(40)	497.6±55.5	(19)	F1	12.50 *	**N>S**
		non	88	566.6±53.0	(23)	500.5±70.8	(45)	471.8±75.5	(20)	F2	32.25 *	6, 5>4
										F3	1.35	
	Tag	select	56	956.4±83.2	(12)	803.3±89.0	(28)	745.7±100.2	(16)	F1	3.90 *	S>N
Whole body		non	111	984.6±117.5	(31)	875.9±105.8	(57)	798.9±82.5	(23)	F2	28.72 *	6>5>4
jump to the forward										F3	0.49	
(Reaction-3)	Soccer	select	56	956.4±83.2	(14)	803.3±89.0	(27)	745.7±100.2	(15)	F1	8.11 *	S>N
		non	111	984.6±117.5	(29)	875.9±105.8	(58)	798.9±82.5	(24)	F2	36.41 *	6>5>4
										F3	0.58	
	Play house	select	79	1009.5±118.6	(20)	865.4±110.3	(40)	801.0±69.4	(19)	F1	6.15 *	**N>S**
		non	88	945.1±87.5	(23)	845.2±102.5	(45)	755.5±107.1	(20)	F2	37.45 *	6>5>4
										F3	0.66	

*p<0.05, unit : msec, F1 : Category, F2 : Age, F3 : Interaction (Category×Age)

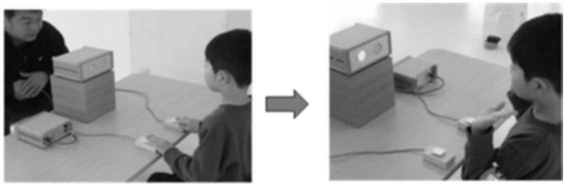


Figure 1 Measurement of Reaction-1

Measurement ran from confirming the light stimulation that a tester sends randomly, to quickly releasing both hands (fingers) from the switch.

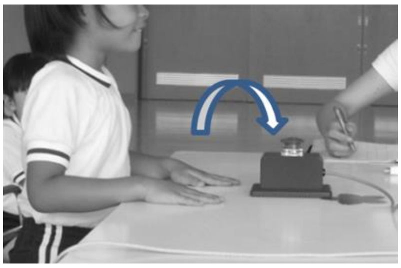


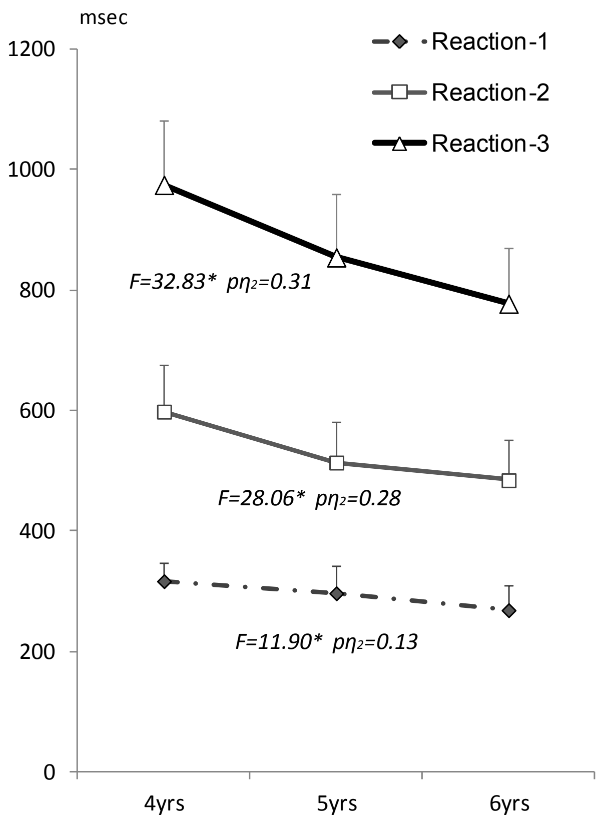
Figure 2 Measurement of Reaction-2

Reaction time measurement ran from confirming the light stimulation that a tester sends randomly, to pressing the forward switch quickly.

Figure 3 Measurement of Reaction-3

Reaction time measurement ran from confirming the light stimulation that a tester sends randomly, until subjects jumped to the forward mat.

Figure 4 Picture cards depicting favorite plays



F: F-value *pη2*: Partial eta squared *: P<0.05

Figure 5 Changes of each reaction time with age

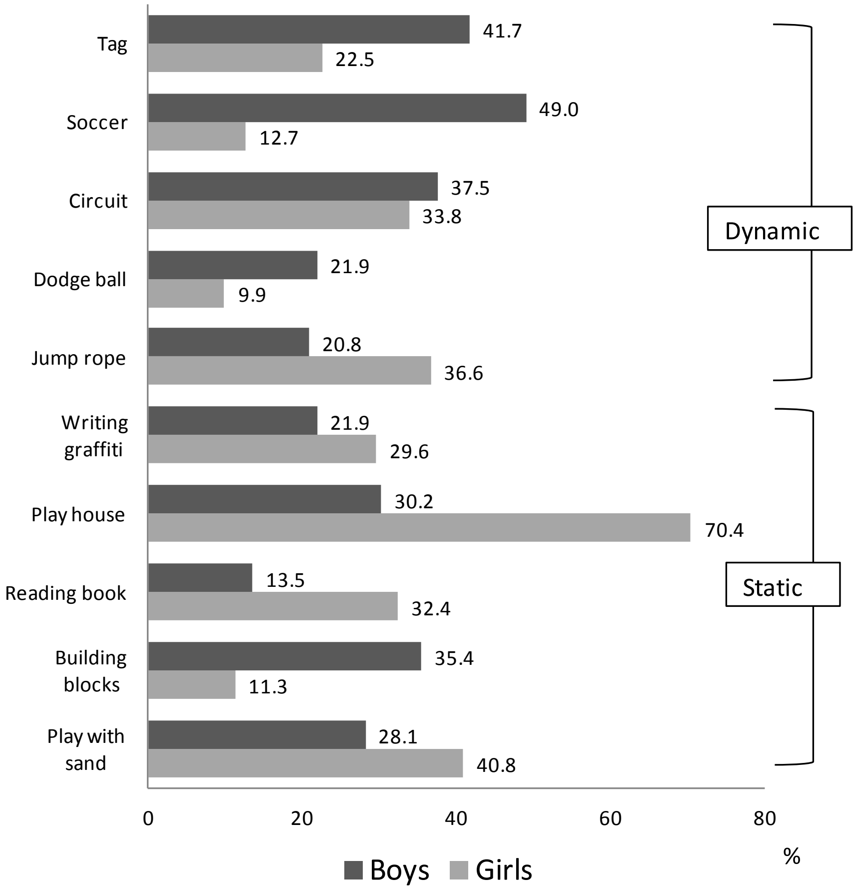


Figure 6 Frequency distribution of plays selected by children as favorites

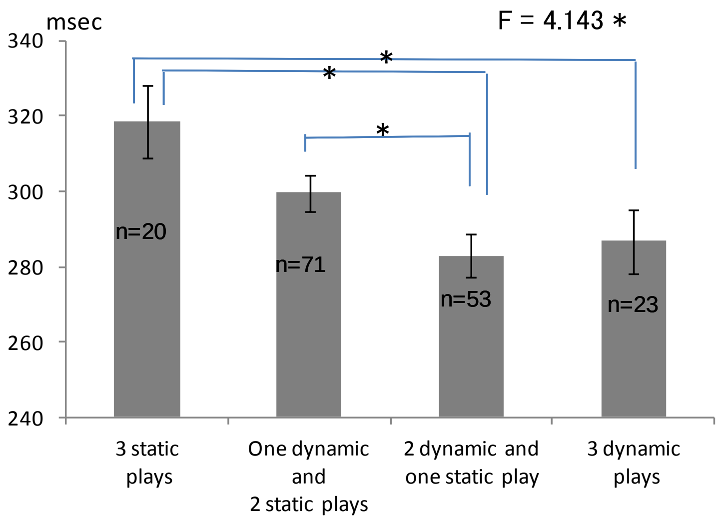


Figure 7 Results of ANCOBA that examined the mean differences among each group divided based on selected number of dynamic plays for reaction -1 (upper-limbs: release movement)

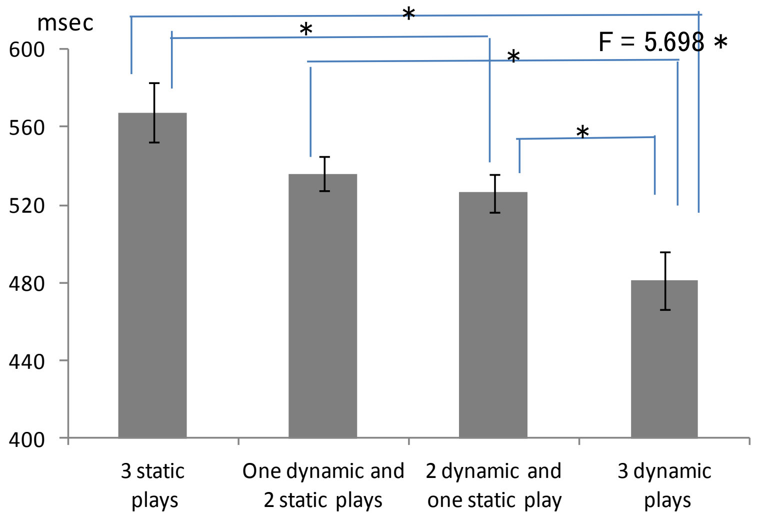


Figure 8 Results of ANCOBA that examined the mean differences among each group divided based on selected number of dynamic plays for reaction -2 (upper-limbs: press movement)

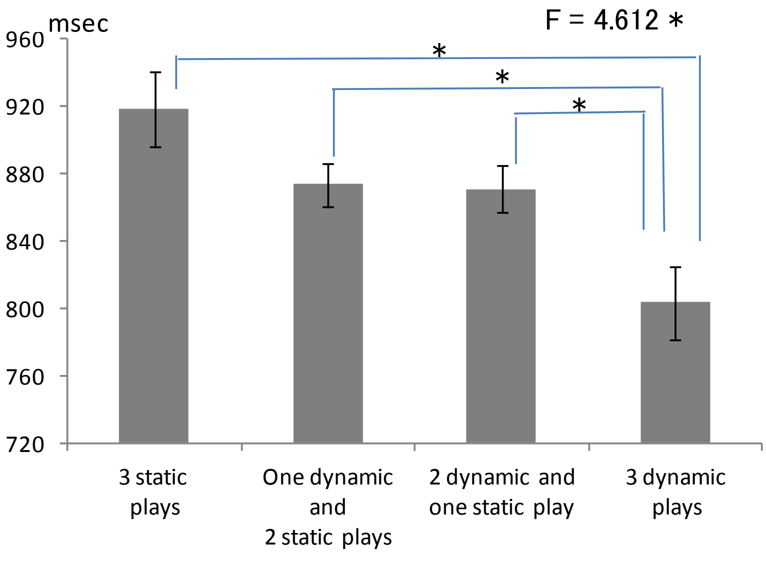


Figure 9 Results of ANCOBA that examined the mean differences among each group divided based on selected number of dynamic plays for reaction -3 (whole body: jump to the forward)